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Inventor(s): ZHANG ZIQING ;

Applicant(s): PIONEER ELECTRONIC CORP (JP) ;

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Equivalents: JP6062488 ;

ABSTRACT:

Speaker units SP1' - SPm; SP1' - SPn of a speaker system are arranged in a two-dimensional array and supplied via digital filters DF1 - DFm, DF1 - DFn to control the directivity of the units. The speaker units are divided and arranged in accordance with frequency reproduction range to form a plurality of loudspeaker groups 28, 36 each having a plurality of speaker units SP1 - SPm; SP1 - SPn. The digital filters are separated into a plurality of digital filter groups 24, 32 connected to the respective loudspeaker groups 28, 36, and each digital filter 24, 32 group has a plurality of digital filters DF1 - DFm; DF1 - DFn respectively connected to the speaker units SP1 - SPm; SP1 - SPn of the associated loudspeaker groups 28, 36. The digital filter groups 24, 32 are driven at sampling frequencies corresponding to the frequency reproduction ranges of the associated loudspeaker groups 28, 36. The system allows control of the directivity over a wide frequency range.

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(71) Applicant(s)
**Pioneer Electronic Corporation**

**(Incorporated in Japan)**

**No 4-1 Meguro 1-chome, Meguro-ku, Tokyo, Japan**

(72) Inventor(s)
**Ziqing Zhang**

(74) Agent and/or Address for Service
**Marks & Clerk**
**57-60 Lincoln's Inn Fields, LONDON, WC2A 3LS, United Kingdom**

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**GB 2259426 A**

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UK CL (Edition L) **H4J JGB JGC JGX**
INT $CL^5$ **H04R 1/20 1/32 1/40 3/00 3/12 3/14**
**Online databases: WPI**

(54) **Speaker system with controlled directivity**

(57) Speaker units $SP_1$, - $SP_m$; $SP_1$, - $SP_n$ of a speaker system are arranged in a two-dimensional array and supplied via digital filters $DF_1$ - $DF_m$, $DF_1$ - $DF_n$ to control the directivity of the units. The speaker units are divided and arranged in accordance with frequency reproduction range to form a plurality of loudspeaker groups 28, 36 each having a plurality of speaker units $SP_1$ - $SP_m$; $SP_1$ - $SP_n$. The digital filters are separated into a plurality of digital filter groups 24, 32 connected to the respective loudspeaker groups 28, 36, and each digital filter 24, 32 group has a plurality of digital filters DF1 - DFm; DF1 - DFn respectively connected to the speaker units $SP_1$ - $SP_m$; SP1 - $SP_n$ of the associated loudspeaker groups 28, 36. The digital filter groups 24, 32 are driven at sampling frequencies corresponding to the frequency reproduction ranges of the associated loudspeaker groups 28, 36. The system allows control of the directivity over a wide frequency range.

FIG.2A

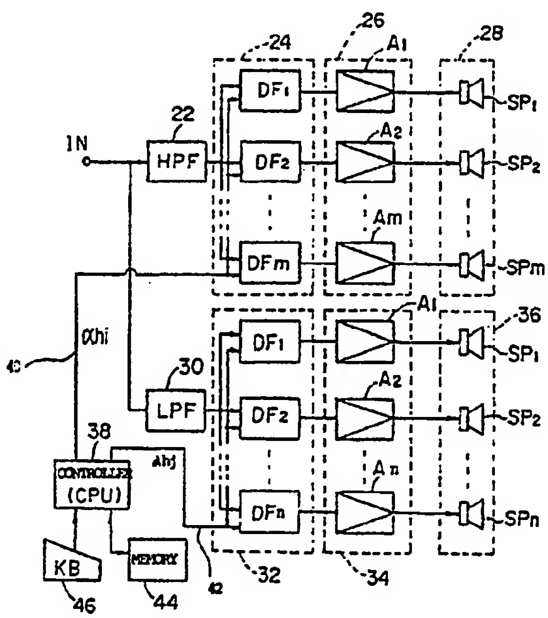
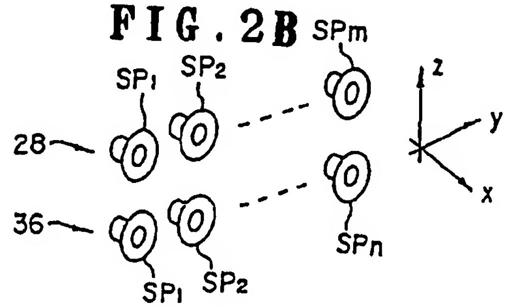



FIG.2B

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

FIG. 1

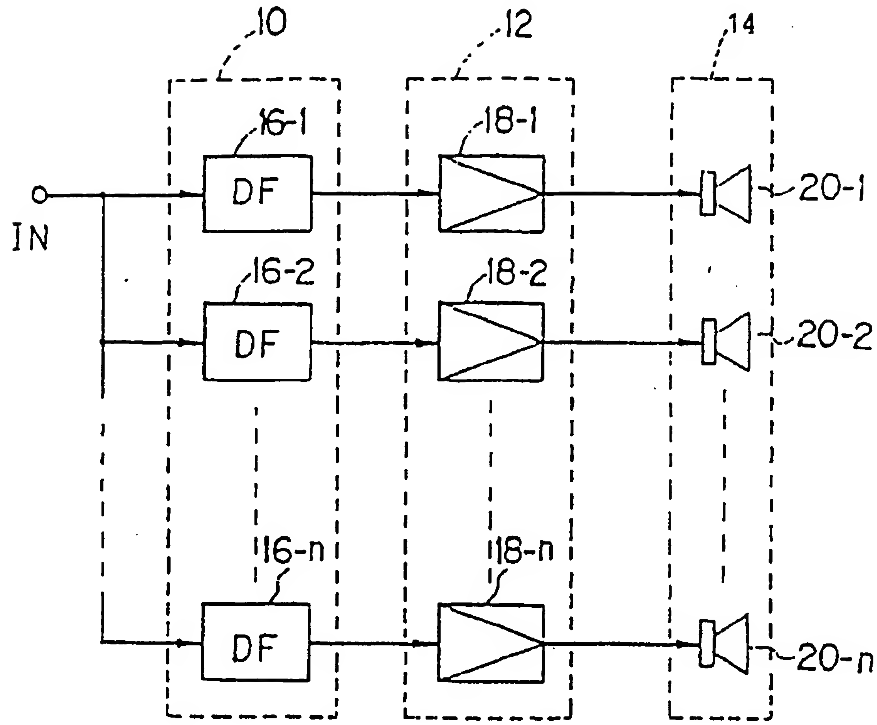
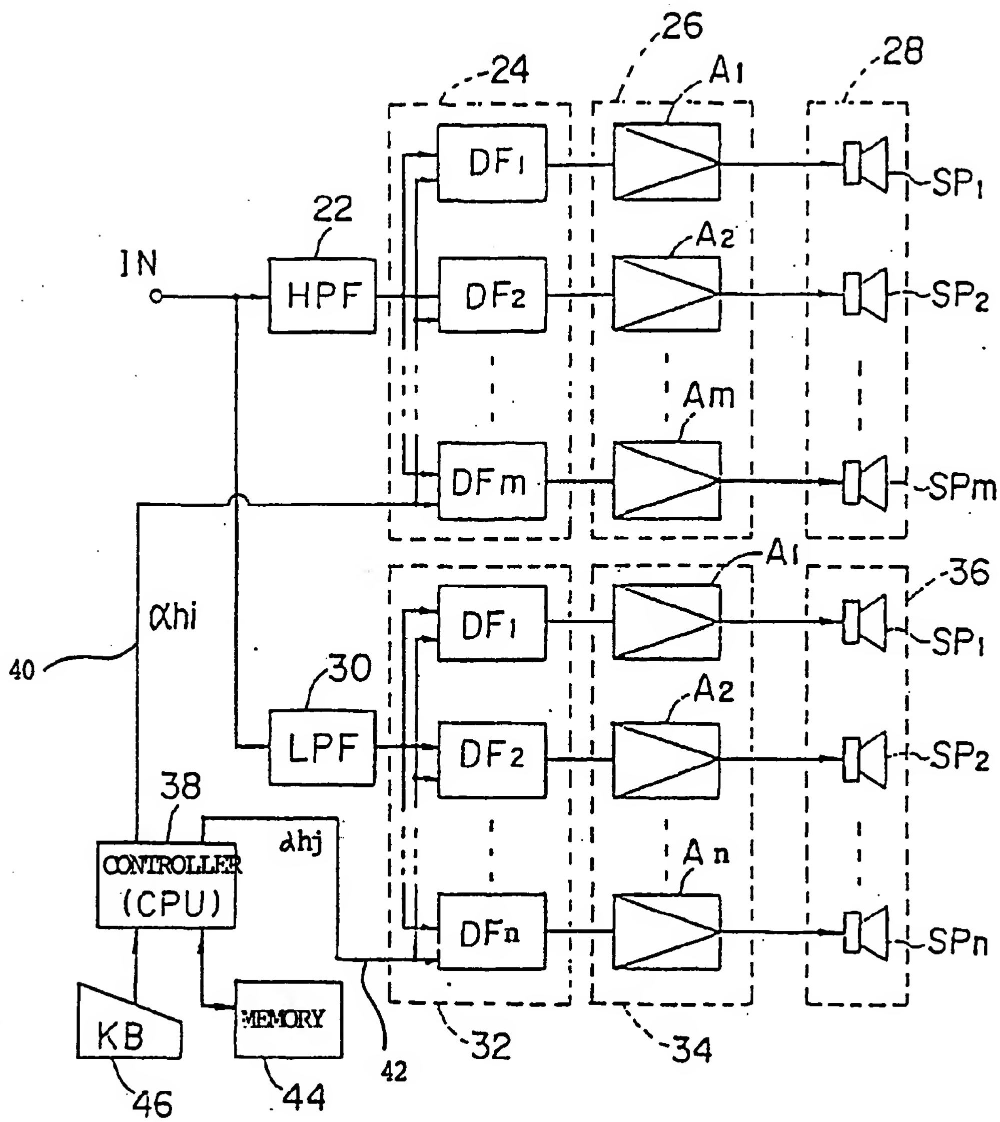
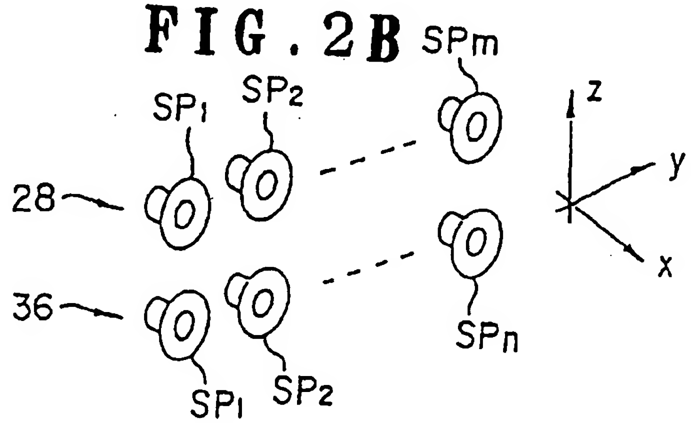


FIG. 2A



26
28
24
A1
DF1
SP1
22
A2
IN
HPF
DF2
SP2
Am
DFm
SPm
A1
36
αhi
DF1
SP1
40
30
A2
LPF
DF2
SP2
38
αhj
An
CONTROLLER
(CPU)
DFn
SPn
KB
MEMORY
42
32
34
46
44


FIG. 2B



SPm
SP2
SP1
z
y
28
x
36
SPn
SP1
SP2

SPEAKER SYSTEM

The present invention relates to a speaker system, and, more particularly, to a directivity-controlled speaker system of a planar array type.

One of characters to evaluate the performance of loudspeakers is "directivity". The directivity is a property that the magnitude of the sound pressure differs depending on the directions. In general, it does not necessarily mean that the wider this directivity becomes, the better the performance of loudspeakers is. The desired pattern will vary depending on the purpose of loudspeakers, i.e., the service range of the loudspeakers. For instance, a wider directivity is often demanded for an audio usage, while a narrow directivity is demanded so as to radiate sound waves in a specific direction to prevent howling or the like for public addressing.

In the case of a single speaker unit, the factors to determine the directivity of loudspeakers include the structure of the speaker unit itself, such as a cone type or horn type, and the depth of the cone of the diaphragm when it is a cone loudspeaker. There is a linear array

type loudspeaker using a plurality of speaker units (so-called Tonsäule type) which radiates sound waves only in a specific direction. In any case, the directivity of loudspeakers is determined by the physical structure of the speaker unit itself or the arrangement of the speaker units. It takes much labor and time to produce a loudspeaker which satisfies the demanded directivity, and this production is often restricted by the size of the loudspeaker or the like. In this respect, speaker systems which use digital filters to electrically control the directivity pattern have been developed (as disclosed in Japanese Patent Application Kokai No. H2-239798). Fig. 1 shows a block circuit of such a speaker system.

In Fig. 1, reference numerals "10", "12" and "14" respectively denote a group of digital filters, a group of amplifiers and a group of loudspeakers. The digital filter group 10 includes n digital filters (e.g., FIR (Finite Impulse Response) filters 16-1, 16-2, •••, and 16-n, the amplifier group 12 includes n amplifiers 18-1, 18-2, •••, and 18-n, and the loudspeaker group 14 includes n full-range speaker units 20-1, 20-2, •••, and 20-n. The digital filters 16-1, 16-2, •••, and 16-n are respectively connected to the speaker units 20-1, 20-2, •••, and 20-n via the associated amplifiers 18-1, 18-2, •••, and 18-n. A common input signal is supplied to the

digital filters 16-1, 16-2, ···, and 16-n from a common input signal terminal IN.

With the above structure, the directivities of the speaker units 20-1, 20-2, ···, 20-n are controlled by adjusting the filter coefficients of the digital filters 16-1, 16-2, ···, 16-n so that the optimal directivity of the whole loudspeaker group 14 can be attained.

In the conventional speaker system as shown in Fig. 1, when the speaker units are driven by a low-frequency signal, the speaker units vibrate to and fro, generating regular waves. When the speaker units are driven by a high-frequency signal, however, the diaphragm of each speaker unit cannot follow up the high-frequency signal and partial vibration occurs on the surface of the diaphragm. As a result, sound waves are generated in all the directions, making the directivity of the loudspeaker difficult or uncontrollable.

If each digital filter is constituted of an FIR filter, many filter taps are needed to control the directivity even at a sufficiently low frequency when the sampling frequency is high.

It is therefore an object of the present invention to provide a speaker system which can easily control the directivity over a wide reproduction range from a low-

frequency range to a high-frequency range.

To achieve this object, according to the present invention, there is provided a speaker system comprising a plurality of speaker units two-dimensionally arranged in a vertical direction and/or a horizontal direction; and a plurality of digital filters through which a signal from a common input signal source is supplied to the plurality of speaker units, whereby directivities of the speaker units are controlled by changing characteristics of the associated digital filters, the plurality of speaker units being divided and arranged in accordance with a reproduction range of the common input signal to form a plurality of loudspeaker groups each having a plurality of speaker units, the plurality of digital filters being separated into a plurality of digital filter groups respectively connected to the plurality of loudspeaker groups and each having a plurality of digital filters respectively connected to the speaker units of the associated loudspeaker group, the plurality of digital filter groups being driven at sampling frequencies corresponding to reproduction ranges of the associated loudspeaker groups.

According to the present invention, a plurality of speaker units are divided and arranged into, for example, a loudspeaker group for treble-range reproduction and a

loudspeaker group for mid- and bass-range reproduction in accordance with the reproduction range of a common input signal. The common input signal is supplied to the loudspeaker groups via the associated digital filter groups. The digital filter groups are driven at sampling frequencies corresponding to reproduction ranges of the associated loudspeaker groups. For instance, the sampling frequency for the digital filter group corresponding to the loudspeaker group for treble-range reproduction is set high, while that corresponding to the loudspeaker group for mid- and bass-range reproduction is set low. This structure can ensure easy control of the directivity over a wide reproduction range from a low-frequency range to a high-frequency range.

Fig. 1 is a block diagram of a conventional speaker system; and

Figs. 2A and 2B illustrate a speaker system according to one embodiment of the present invention, and are respectively a block diagram of the speaker system and a perspective view showing the arrangement of loudspeakers.

A preferred embodiment of the present invention will now be described referring to the accompanying drawings.

Figs. 2A and 2B illustrate a speaker system according to one embodiment of the present invention, Fig. 2A being a block diagram of the speaker system while Fig. 2B is a perspective view showing the arrangement of loudspeakers.

As shown in Fig. 2A, the speaker system has one common input signal terminal IN which is connected via a high-pass filter 22 to a plurality of parallel treble-range speaker units $SP_1$ to $SP_m$, so that the individual speaker units $SP_1$-$SP_m$ are driven in parallel by the high-frequency component of the common input signal. As illustrated, pairs of digital filters $DF_1$ to $DF_m$ and amplifiers $A_1$ to $A_m$ are respectively inserted in series in the signal lines running from the high-pass filter 22 to the speaker units $SP_1$-$SP_m$. The digital filters $DF_1$-$DF_m$, amplifiers $A_1$-$A_m$ and speaker units $SP_1$-$SP_m$ are respectively called a digital filter group 24, an amplifier group 26, and a treble-range speaker unit group 28.

Likewise, the common input signal terminal IN is connected via a low-pass filter 30 to a plurality of parallel mid- and bass-range speaker units $SP_1$ to $SP_n$, so that the individual speaker units $SP_1$-$SP_n$ are driven in parallel by the mid- and low-frequency component of the common input signal. As illustrated in Fig. 2A, pairs of

digital filters $DF_1$ to $DF_n$ and amplifiers $A_1$ to $A_n$ are respectively inserted in series in the signal lines running from the low-pass filter 30 to the speaker units $SP_1$-$SP_n$. The digital filters $DF_1$-$DF_n$, amplifiers $A_1$-$A_n$ and speaker units $SP_1$-$SP_n$ are respectively called a digital filter group 32, an amplifier group 34, and a mid- and bass-range speaker unit group 36.

The individual digital filters $DF_1$-$DF_m$ in the digital filter group 24 and the individual digital filters $DF_1$-$DF_n$ in the digital filter group 32 are respectively connected to signal lines 40 and 42 running from a controller (CPU) 38. Through the signal lines 40 and 42, the controller 38 sets filter coefficient data $\alpha hi$ and $\alpha hj$, specific to the respective digital filters $DF_1$-$DF_m$ and $DF_1$-$DF_n$, into the digital filters $DF_1$-$DF_m$ and $DF_1$-$DF_n$. The filter coefficient data $\alpha hi$ and $\alpha hj$, which are stored in a memory 44, are sequentially set into the digital filters $DF_1$-$DF_m$ and $DF_1$-$DF_n$ by an instructional operation of an input keyboard 46.

As shown in Fig. 2B, the treble-range speaker units $SP_1$-$SP_m$ are linearly arranged at equal intervals in one direction (for example, in the direction of the y-coordinate axis), forming a speaker array. Likewise, the mid- and bass-range speaker units $SP_1$-$SP_n$ are linearly arranged at equal intervals in one direction (for

example, in the direction of the y-coordinate axis), forming a speaker array. The individual treble-range speaker units $SP_1$-$SP_m$ preferably have the same physical characteristics or various factors (the diameter, the minimum resonance frequency, the mass of the diaphragm, etc.) which define the characteristics of the speaker units. It is also preferable that the individual mid- and bass-range speaker units $SP_1$-$SP_n$ preferably have the same physical characteristics. The range of the reproduction frequency of the speaker units, i.e., the type of the speaker units, such as a woofer, squawker, tweeter or full range speaker, may suitably be selected, in accordance with the usage. Whether the speaker units should be retained in the respective enclosures or should be mounted on a single continuous baffle, a wall or the like, though not illustrated, would differ depending on the use of the speaker system, and the proper structure has only to be appropriately selected. In Fig. 2B, the x axis represents the direction of sound radiation, the y axis the lateral direction (or horizontal direction), and the z axis the longitudinal direction (or vertical direction).

The digital filters $DF_1$-$DF_m$ and $DF_1$-$DF_n$ are accomplished by a digital signal processor (DSP), and are constituted of typical linear type FIR (Finite Impulse

[[

Response) filters. Though not illustrated, each digital filter comprises an ALU (Arithmetic Logic Unit) for performing arithmetic operations and logical operations which are the essential portion of signal processing, a sequencer (including a program counter, instruction registers and a decoder) for controlling an operational sequence, a ROM (Read Only Memory) where the necessary programs are stored, a RAM (Random Access Memory) for storing data, registers for temporary storage of data, an input/output port for exchanging data with an external unit, and a bus which connects those individual elements.

The digital filters $DF_1$-$DF_m$ and $DF_1$-$DF_n$ have the same structure (the same number of taps and the same coefficient for the multipliers).

In the above-described arrangement, the high-frequency component of the common input signal from the common input signal terminal IN is extracted by the high-pass filter 22 (e.g., $f_c$ = 2.5 KHz). This high-frequency component is supplied to the digital filters $DF_1$-$DF_m$ whose outputs are in turn supplied via the associated amplifiers $A_1$-$A_m$ to the treble-range speaker units $SP_1$-$SP_m$. The digital filters $DF_1$-$DF_m$ are driven at a sampling frequency $f_s$ of 20 KHz to control the directivities of the treble-range speaker units $SP_1$-$SP_m$ within the range of 2.5

KHz to 10 KHz.

The high-frequency component of the common input signal from the common input signal terminal IN is cut off by the high-cut filter 30, thus yielding a mid- and low-frequency component. This mid- and low-frequency component is supplied to the digital filters $DF_1$-$DF_n$ whose outputs are in turn supplied via the associated amplifiers $A_1$-$A_n$ to the mid- and bass-range speaker units $SP_1$-$SP_n$. The high-cut filter 30 may be omitted so that the common input signal is supplied directly to the digital filters $DF_1$-$DF_n$. The digital filters $DF_1$-$DF_n$ are driven at a sampling frequency $F_s$ of 5 KHz to control the directivities of the mid- and bass-range speaker units $SP_1$-$SP_n$ within the range of 0 KHz to 5 KHz.

In the speaker system according to this embodiment of the present invention, the reproduction of the high-frequency component is executed by the treble-range speaker units, and the sampling frequency for the digital filters that controls the directivities of the treble-range speaker units is set high to control the treble-range directivity. It is therefore possible to easily control the directivity over the entire reproduction range from the mid- and low-frequency component to the high-frequency component.

If the coefficients of the multipliers of the individual digital filters are set equal to one another as in this embodiment, the coefficient data can be sent to the individual digital filters simultaneously so that the directivity can be altered spontaneously (or data transfer becomes easier). Further, only a single table is needed to store the filter coefficients of the digital filters.

Although the digital filters are constituted of FIR filters in this embodiment, they may be constituted of IIR (Infinite Impulse Response) filters as well.

While the individual digital filters have the same structure in this embodiment, they may take different structures.

Although the filter coefficients of the digital filters are computed by a non-linear optimizing technique (proposed in Japanese Patent Application No. H3-197864) in this embodiment, the present invention can be applied to a speaker system which does not employ the optimizing technique (as disclosed in, for example, Japanese Patent Application Kokai No. H2-239798).

As described above, according to the present invention, the reproduction of the high-frequency component is executed by the treble-range loudspeakers, and the sampling frequency for the treble-range digital

**CLAIMS:**

1. A speaker system comprising:

a plurality of speaker units two-dimensionally arranged in a vertical direction and/or a horizontal direction; and

a plurality of digital filters through which a signal from a common input signal source is supplied to said plurality of speaker units, whereby directivities of said speaker units are controlled by changing characteristics of the associated digital filters,

the plurality of speaker units being divided and arranged in accordance with a reproduction range of said common input signal to form a plurality of loudspeaker groups each having a plurality of speaker units,

the plurality of digital filters being separated into a plurality of digital filter groups respectively connected to said plurality of loudspeaker groups and each having a plurality of digital filters respectively connected to said speaker units of the associated loudspeaker group,

said plurality of digital filter groups being driven at sampling frequencies corresponding to reproduction ranges of the associated loudspeaker groups.

2. The speaker system according to Claim 1, wherein said plurality of speaker units in each of said loudspeaker

groups have the same physical characteristic.

3. The speaker system according to Claim 1, further comprising filters corresponding to reproduction ranges of said loudspeaker groups.

4. The speaker system according to Claim 1, wherein said digital filters are constituted of digital signal processors.

5. The speaker system according to Claim 1, wherein said plurality of digital filter groups are driven at sampling frequencies different from one another and corresponding to reproduction ranges of the associated loudspeaker groups.

6. The speaker system according to Claim 5, wherein those digital filters in each of said digital filter groups have the same number of taps and the same filter coefficient is supplied to multipliers of said digital filters.

| Patents Act 1977<br>**Examiner's report to the Comptroller under Section 17** – 15 –<br>**(The Search report)** | Application number<br>GB 9316621.3 |
|---|---|
| **Relevant Technical Fields**<br>(i) UK Cl (Ed.L) H4J (JGB, JGC, JGX)<br>(ii) Int Cl (Ed.5) H04R 1/20, 1/32, 1/40, 3/00, 3/12, 3/14 | Search Examiner<br>P J EASTERFIELD<br><br>Date of completion of Search<br>13 OCTOBER 1993 |
| Databases (see below)<br>(i) UK Patent Office collections of GB, EP, WO and US patent specifications.<br><br>(ii) ONLINE DATABASES : WPI | Documents considered relevant following a search in respect of Claims :-<br>1 TO 6 |

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X: Document indicating lack of novelty or of inventive step.

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A: Document indicating technological background and/or state of the art.

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E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family; corresponding document.

| Category | Identity of document and relevant passages | Relevant to claim(s) |
|---|---|---|
| A,P | GB 2259426 A (PIONEER) | |

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